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CHARACTERIZATION, ANALYSIS AND PROPERTIES OF MATERIAL WITH RENEWABLE SOURCES RAW MATERIALS

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ABSTRACT: In recent years the need of healthy textile led to the introduction of a number of new fibres around the world. Bamboo fibre, a multifunctional fibre is one of them. The paper deals with the preparation, structure and properties of fibrous materials based on synthetic and microbial polymers. The fibrous materials' properties are possible to be investigated by methods of physical and mechanical characterization, microscopy, thermal conductivity by using Alambeta and chemical characterization. The results of experiments with knitted fabric prepared from PLA, polypropylene and bamboo fibres were evaluated by using Alambeta. Bamboo includes antimicrobial and bacteriostatic ingredients. Effect of content of these ingredients remains during many processes. The characterization confirms good smell absorbability, water absorbability and that it has good isolation properties against heat.

KEYWORDS: bamboo fibre, antimicrobial, microbial polymers

1. INTRODUCTION

Nowadays are the researchers mainly interested in microbial polymer systems that are synthesized on the renewable and non-toxic product basis. The most significant process is now the polylactides production. Thanks to their biodegradation, biocompatibility and very good mechanical properties they have gradually found their use in various spheres. Industrially, polylactic acid is made of agricultural products containing starch (maize, potatoes, white beet, sugar cane, waste biomass). Bamboo does not require replanting after harvesting because its vast root network continually sprouts new shoots while pulling in sunlight and greenhouse gases and converting them to new green growth. Bamboo fiber is biodegradable and the decomposition process does not cause any environmental pollution [1].

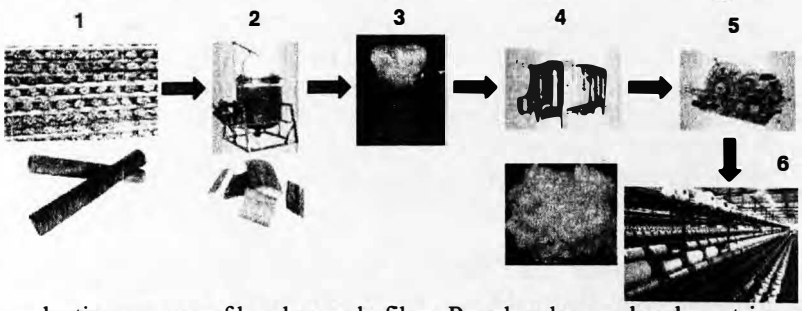


Fig. 1: The production process of bamboo pulp fibre: Raw bamboo → bamboo strip → steaming of bamboo strip → crushing and decomposing → biological enzyme degumming → fibre carding → natural original bamboo fibre

Bamboo and Polylactide fibres

Bamboo fibre is a particular type of regenerated cellulose fibre made of basic raw material, bamboo cellulose, which is prepared from bamboo by means of hydrolysis-alkalization and multi-phase bleaching. Bamboo cellulose is then transformed into fibres by means of a mechanism similar to the one used for the preparation of viscose fibres [1-3]. Bamboo fibre has particular and natural functions of anti-bacteria, bacteriostatic and deodorization. It is validated by Japanese Textile Inspection Association that, even after fifty times of washing, bamboo fibre fabric still possesses excellent function of anti-bacteria, bacteriostatic. Its test result shows over 70 % death rate after bacteria being incubated on bamboo fibre fabric. Bamboo fibre's natural anti-bacteria function differs greatly from that of chemical antimicrobial. The latter often tends to cause skin allergy when added to apparel [1-4].

Products from bamboo fibres have low weight and they are permeable. It is this permeability of clothes made of bamboo that allows a pleasant feeling of cold during particularly hot summer. Such clothes do not stick on the body even in extremely warm weather. Clothes from bamboo fibres are sometimes also called Air Conditioning Dress [1-4].

Tab. 1: Physical parameters of bamboo and PLLA fibres [4]

Properties	**BF**	**Properties**	**PLA**
Dry tensile strength (cN/dtex)	2.33	Density (g/cm^3)	1.27
Wet tensile strength (cN/dtex)	1.37	Melting temperature (°C)	175
Dry elongation at break (%)	23.8	Crystallization temperature (°C)	103
Linear density percentage of deviation (%)	-1.8	Glass transition temperature (°C)	58
Percentage of length deviation (%)	-1.8	Residual humidity (%)*	0.6
Residual sulfur (mg/100g)	9.2	Combustion heat (kJ/kg)	19.000
Defect (mg/100g)	6.4	Breaking strain (cN/dtex) (GPa)	4.0-5.5 0.40-0.55
Whiteness (%)	69.6	Ductility (%)	20-35
Oil content (%)	0.17	Young's module (cN/dtex) (GPa)	60-70 6.0-7.0
Moisture regain (%)	13.03	Shrinkage in boiling water (%)	8-15

*Relative humidity 65 %, t = 25 °C

Bamboo fibre (BF) is a unique biodegradable textile material. As a natural cellulose fibre, bamboo fibre can be 100 % biodegraded in soil by micro organisms and sunlight. Decomposition process does not cause any pollution in the environment. Bamboo fibre comes from nature and completely returns to nature in the end. Bamboo fibre is praised as natural, green and eco-friendly new-type textile material of the 21st century [1-4].

Fibres made of polylactic acid are one of the most promising biodegradable fibres with natural and synthetic fibre properties. Polylactides are made of lactic acid. Lactic acid (α-hydroxypropion acid) is simple natural organic acid that can be found in the bodies of animals, plants and microbes. It can be easily disintegrated in the nature without any harm to the environment. Lactic acid is capable of elf-polycondensation. It has asymmetric carbon and creates two optical isomers. It is made in the process of fermentation as well as L(+) lactic acid. Poly-L-lactic acid (PLLA) has desired crystallinity, while lactic acid copolymer L/D has lower crystallinity, or it is amorphous [1,5,6].

In these days, the greatest attention is paid to physical modifications based on macro-morphology and geometry changes of fibres. Biodegradable fibres can be formed via improper twist. That is why the PLA fibres can be utilized in textiles designed for clothes, soft furnishings, technical textiles and medical implants [1,5,6].

Residual humidity is rather low. Thanks to the above mentioned characteristics, the clothes made of these fibres are cushy, fine and dry. Low breakage index ensures that the clothes are smooth with silk gloss. Melting temperature at 175 °C is the highest from the group of other biodegradable polymers but always requires special attention during ironing. Combustion heat is lower than the combustion heat of other synthetic polymers [1,5,6].

Polylactide properties can be compared to standard thermoplastic or fibrous material. It has been used successfully in medicine and for pharmaceutical purposes. However, PLA attracted more attention for its metamorphoses, i.e. biodegradability and the fact that it is made of renewable resources [1,5,6].

2. EXPERIMENTAL PART

The basic physical and mechanical properties of tested samples PLA – hollow shear fibre produced by Cargill Dow LLC, bamboo fibre form India, and polypropylene (PP) fibre Prolenvel® assortment 84/43 x 2 (Fibrochem) – polylactide fibres – were evaluated in a traditional laboratory environment. The evaluation of basic structural parameters was done by using standard microscopy fibre size and the structure was evaluated. High resolution microscopy was applied in order to reveal the fibre structure and other properties. Bamboo and PLA samples were evaluated by using SIMS for checking the main components and micro- and macro mineral components.

Mechanical properties of fibres are dependent on conditions of their preparation as these conditions determine the structure development. Although in some applications the firmness is not so important, they must provide good level of processing by using appropriate technologies and by use of property of a sample. Table 2 lists measured basic physical and mechanical parameters according to STN EN ISO 2062 of tested PLA, BF, PP fibres. During this evaluation the tencity, relative tencity and elongation of five samples were measured with continuous loading of the samples until the breakdown.

Tab. 2: Specified basic physical and mechanical property values of samples – PLA BF, PP fibres

Sample	100 % PP	100 % PLA	100 % BF
Tencity (cN)	432.05	346.40	264.98
Elongation (%)	69.92	29.20	12.11
Relative tencity (cN/dtex)	2.57	0.56	1.42

a) PLA sample b) BF sample c) PP sample

Fig. 2: High resolution microscopic images of PLA, BF, PP fibres surface

High resolution microscopic images of PLA, BF, PP fibres surface structure is shown in Fig. 2. Images reveal that the surfaces are similar, however the bamboo fibres are more vitiate. Under higher magnification of PP sample the image shows highly oriented smooth fibre surface, which is the result of technological production process.

Bamboo and PLA fibres were characterized by using secondary ion mass spectrometry [7]. The mass spectrum shows the main components as cellulose $C_6H_7O_3$ at m/z 127, $C_6H_9O_4$ at 145 and Lignin $C_8H_9O_2$ at m/z 137, Fig. 3. We also revealed the basic impurities like Na, K, Mg, Ca, which belong to macro minerals and Mn, Fe, Co, Cu, Mo to micro minerals. Bamboo does not contain toxic biometal. PLA fibre spectrum is similar to bamboo fibres. The mass spectra of bamboo and bamboo fibre are similar. Typical mass spectrum from bamboo fibre is shown in Fig. 4. In positive secondary ion spectrum we can identify ions of Na, K, Ca, Mg, Mn, Fe, Si. In negative ion spectrum ions of O and $C_6H_{13}O_5$ at m/z 165 are clearly resolved, which belongs to cellulose fragments. PLA is produced from Lactic acid, which is produced through fermentation of cornstarch. Fragments of polylactid are shown in mass spectra at m/z 73 and at m/z 144. After technological mixing process of BF with PLA the result is a fibre usable for medical purposes for its antibacterial and biodegradable properties.

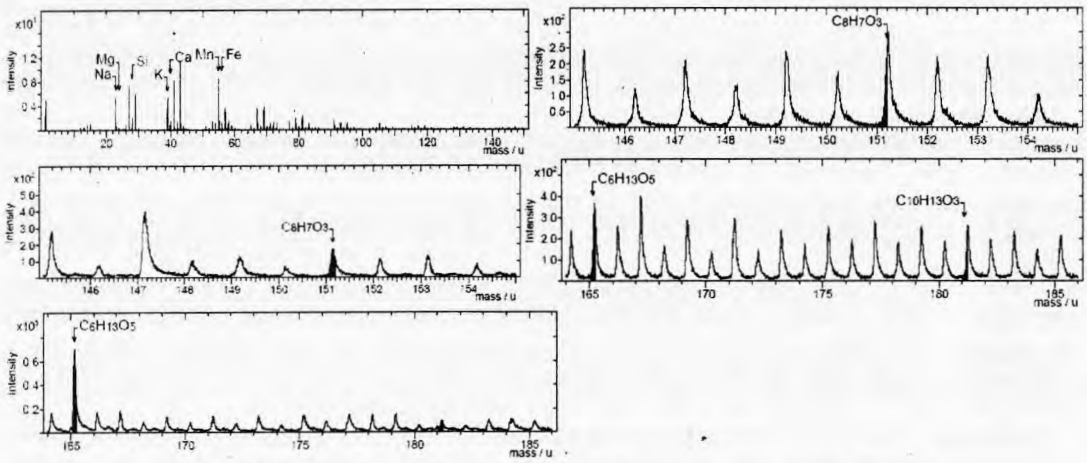


Fig. 3: Mass spectrum of Bamboo with main components and fragments

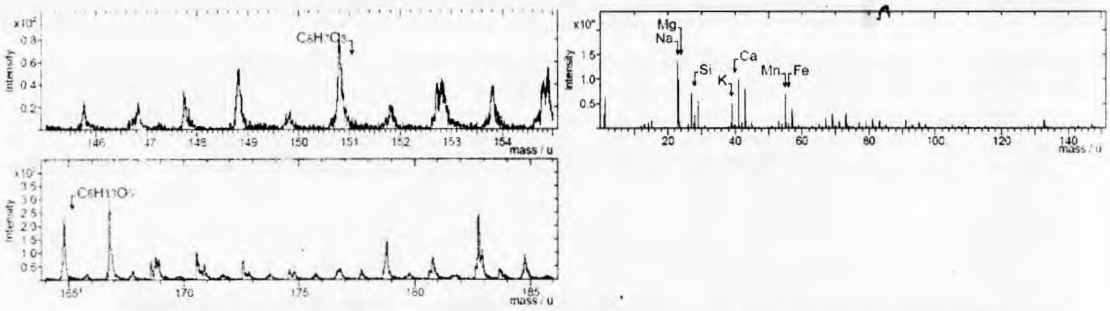
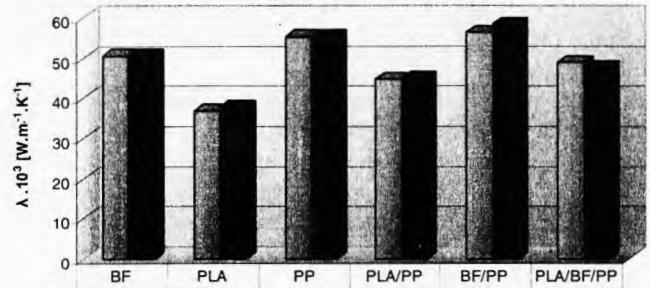


Fig. 4: Mass spectrum of Bamboo fibre with main components and fragments in positive polarity (left) and in negative polarity (right)

Continuous effort was paid for evaluation of knitted fibres using Alambeta instrument according to standard ISO EN 31092. The instrument directly measures the classical stationary thermal properties of fabrics such as the stationary heat flow density, thermal parameters were assessed: thermal conductivity, thermal diffusion, thermal absorption and thermal resistance. Advanced attributes of thermal absorption characterize colder feeling. Thermic palpation testing of textile is strongly affected by their structure and composition in which the humidity is the most important factor.



	BF	PLA	PP	PLA/PP	BF/PP	PLA/BF/PP
R	50,4	36,8	55,2	44,7	56,3	48,8
L	50,6	37,7	55,2	45	58,3	47,7

Fig. 5: Relationship between thermal conductivity of knitted fabrics and their material composition

Knitted fabrics from PP fibres have the best thermal-insulating properties, as shown by their values for thermal conductivity. Based on the measured thermal conductivities, knitted fabrics from BS/PP fibres have better thermal-insulating properties than fabrics from PP fibres, while also having good antimicrobial effects. The evaluation of utility properties of textile clothing products is based on laboratory tests as well as on users' evaluation of wearing properties.

3. CONCLUSION

On the basis of the results of physical-mechanical and structural properties evaluation we can presume that structural parameters and subsequently physical-mechanical properties change in the production process. BF is able to absorb heavy metals and other compounds, which are dangerous for human organism. During chemical analysis of BF we confirmed the absence of heavy metals and the presence of macro and micro minerals. Mixing of bamboo fibre with PLA and PP yields a very good textile material, which can be widely used for medical application, textile industry etc. Knitted fabrics from PP fibres have the best physiological properties, but they are not biodegradable and they need antimicrobial modification. Knitted fabrics from BS/PP mixture are also on a very good level, they have natural antimicrobial effects and are partly biodegradable and biocompatible. As polylactides, bamboo belongs to a new fibre type, availability of resources, causing no harm to environment, and expected primary costs indicate that polylactides are the fibres of the third millennium.

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